# Emergent Higgs

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# 126GeV

What is the microscopic physics behind the Higgs mechanism?

# We know that

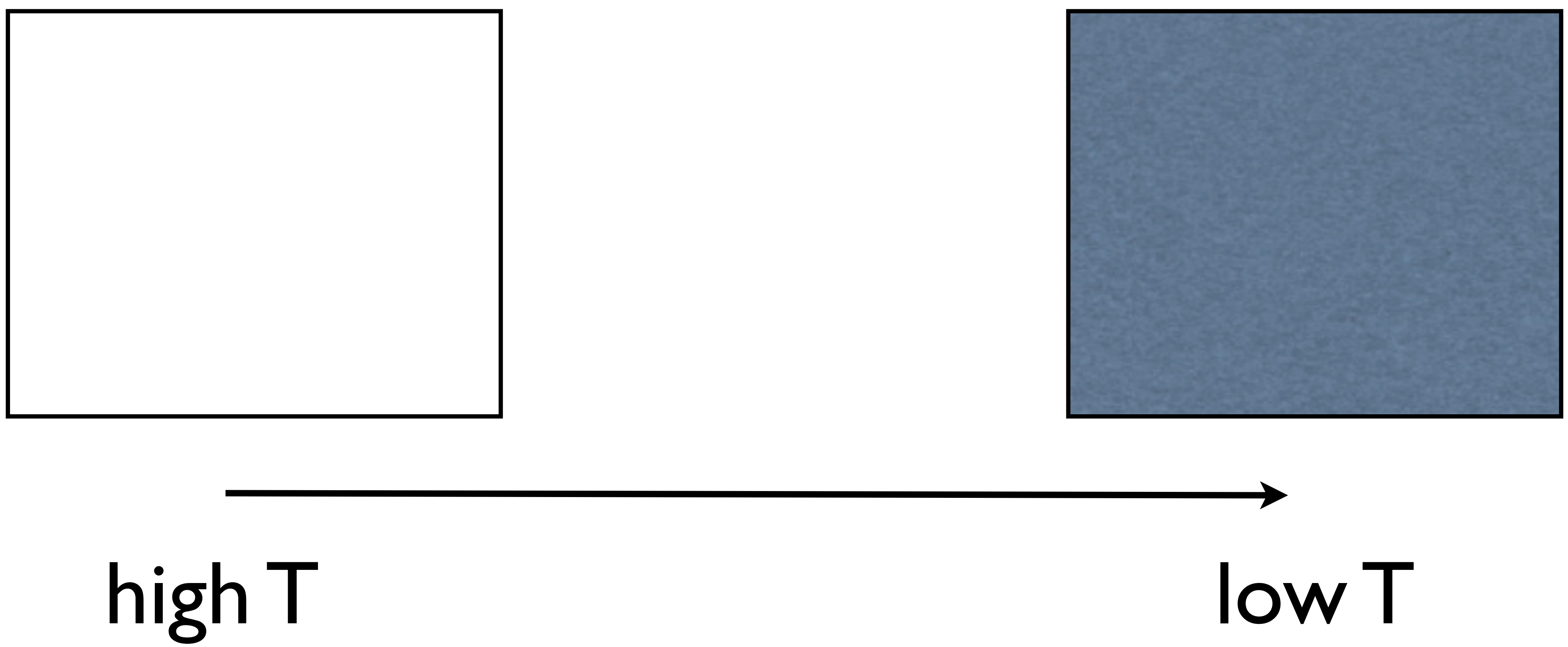
- EWSB happened twice: one by Higgs and another by QCD (chiral symmetry breaking).

There may be a unified framework to understand this.

(Higgs as a part of QCD?)

# What's Higgs?

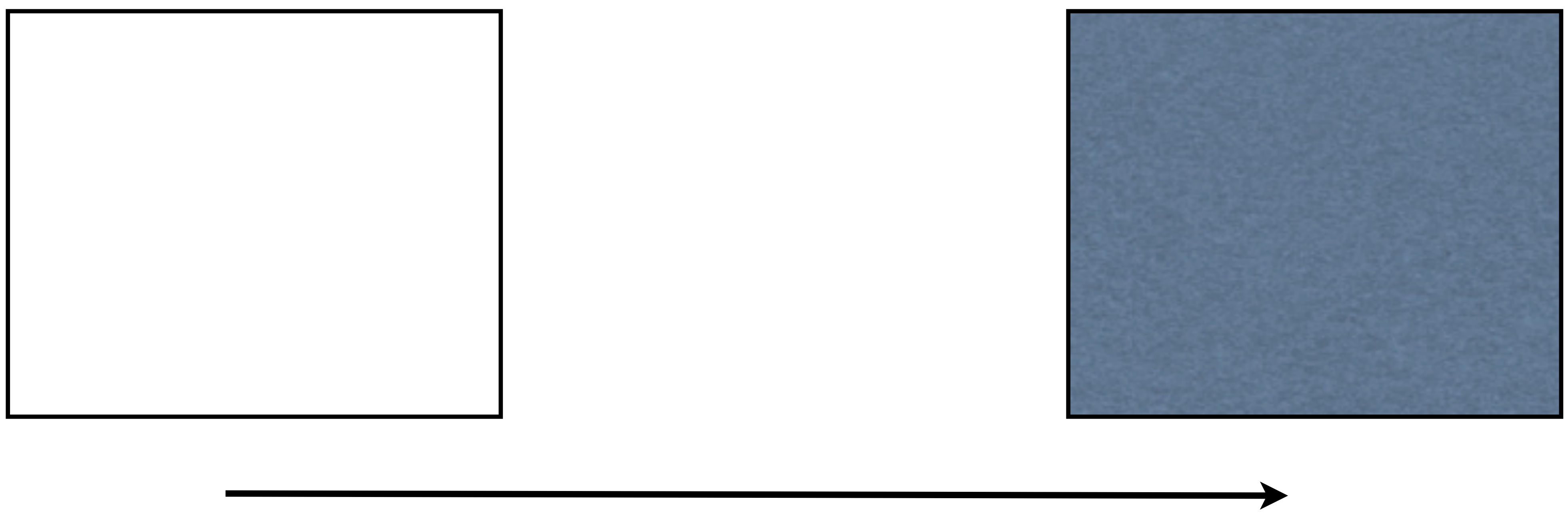
It is pretty similar to superconductivity.




But the theory is just QED.

# What's Higgs?

another example: chiral symmetry breaking

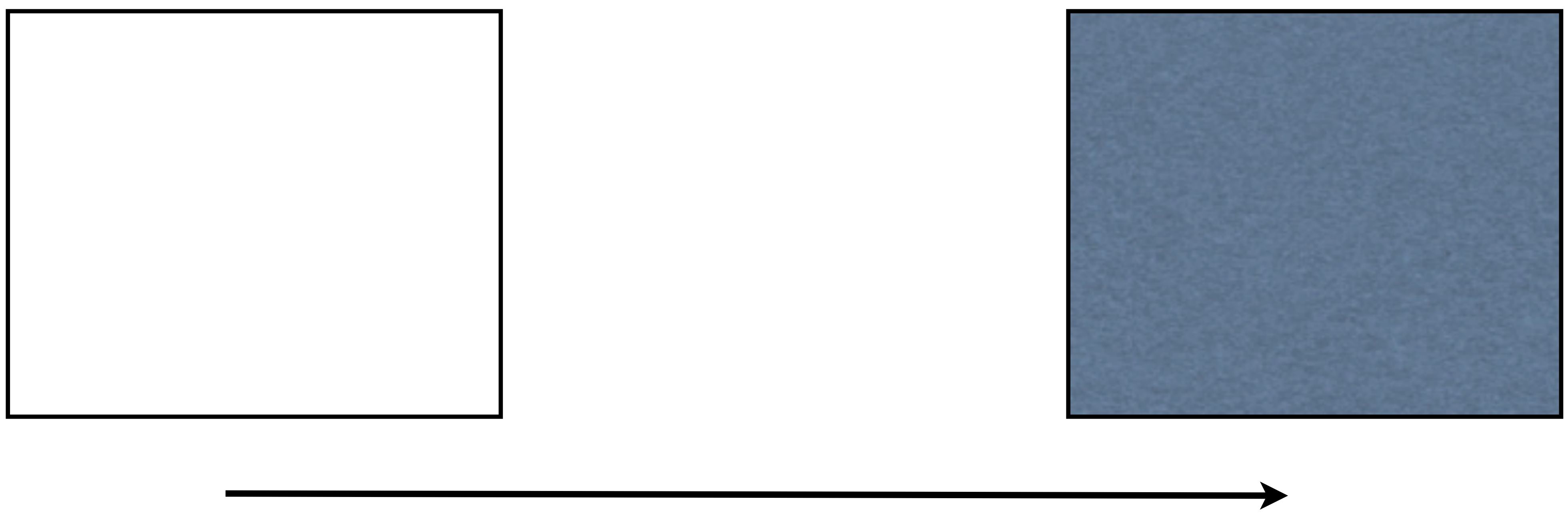


weak coupling strong coupling

But the theory is just QCD.

# hypothesis

Extra dimensional QCD



large extra dim. small extra dim.

the theory is just QCD

# Scenario

Standard Model in extra dim. (no Higgs)

$\downarrow$ compactification
+ non-perturbative effects
of SM gauge interactions

Standard Model (with Higgs)

"Self-breaking"

[Dobrescu '98][Cheng, Dobrescu, Hill '99][Arkani-Hamed, Dimopoulos '98]
[Arkani-Hamed, Cheng, Dobrescu, Hall '00]

# Extra dimensional gauge theory?

5-dimensional gauge theory:

two parameters: $g_5$, R    dim($g_5$)=-1/2

$\longrightarrow$ cut-off scale $\Lambda = \frac{8\pi^2}{g_5^2}$

large extra dim.

$$\frac{1}{R} \ll \Lambda$$

= weakly coupled

$\longrightarrow$ We get a weakly coupled 4D effective theory

$$\frac{1}{g_4^2} = \frac{2\pi R}{g_5^2} = \frac{R\Lambda}{4\pi} \gg \frac{1}{4\pi}$$

small extra dim. or high energy

$$\frac{1}{R} \gg \Lambda \quad \text{or} \quad E \gg \Lambda$$

= strongly coupled

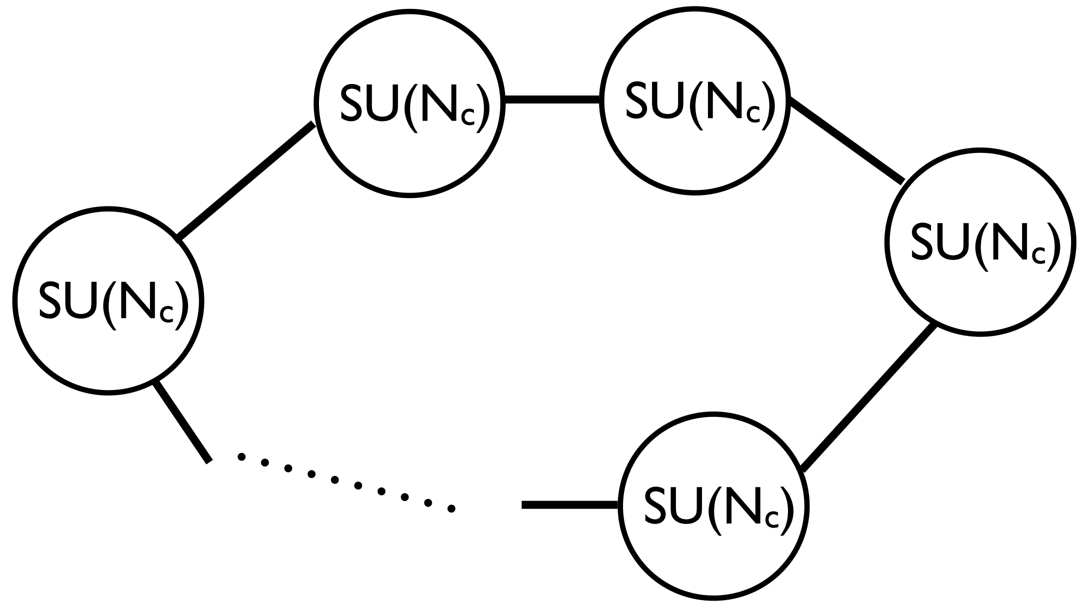
$\longrightarrow$ "???" (non-perturbative)

We hope "???" is going to be our Higgs.

We need a definition of the theory to discuss this region.
(results depend on how we cut off the theory..)

# A (possible) definition of extra dim. theory

It has been proposed that




provides a UV completion.

[Arkani-Hamed, Cohen, Georgi '01]
[Hill, Pokorski, Wang '01][Cheng, Hill, Pokorski, Wang '01]

# Usual story: mimics extra-dimension only at low energy

N-site model: $\frac{1}{R} = \frac{4\pi g v}{N}, \quad \Lambda = \frac{(4\pi)^2 v}{g} \qquad \Lambda_{\mathrm{dec.}} \equiv \frac{N}{R} = 4\pi g v$

g: gauge coupling at each site, v: vev of the link fields

$\downarrow$

The N→∞ limit while fixing R and Λ means

$$g \to \infty, \quad v \to \infty$$

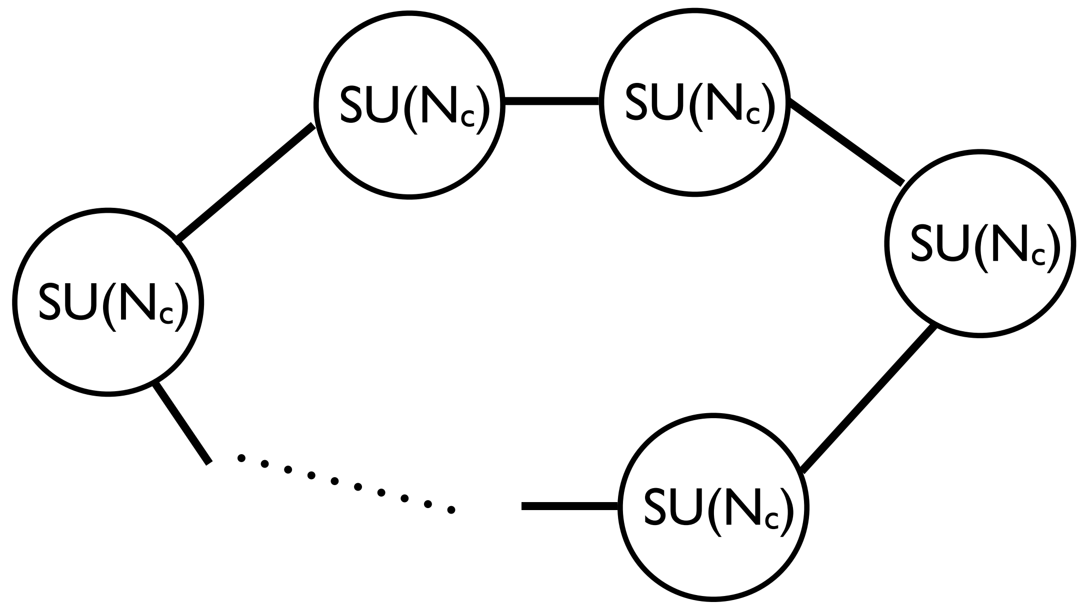
But, we cannot go beyond $g \gg 1$.

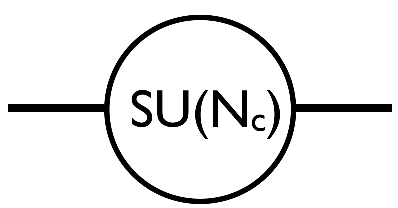
$\longrightarrow$ One cannot take the continuum limit.

$\longrightarrow$ Equivalent to say that we cannot discuss physics beyond the scale Λ since $\Lambda > \Lambda_{\mathrm{dec.}}$

[Arkani-Hamed, Cohen, Kaplan, Karch, Motl '01]

# But with N=2 SUSY,




each site is a finite theory.
$(N_f=2N_c)$

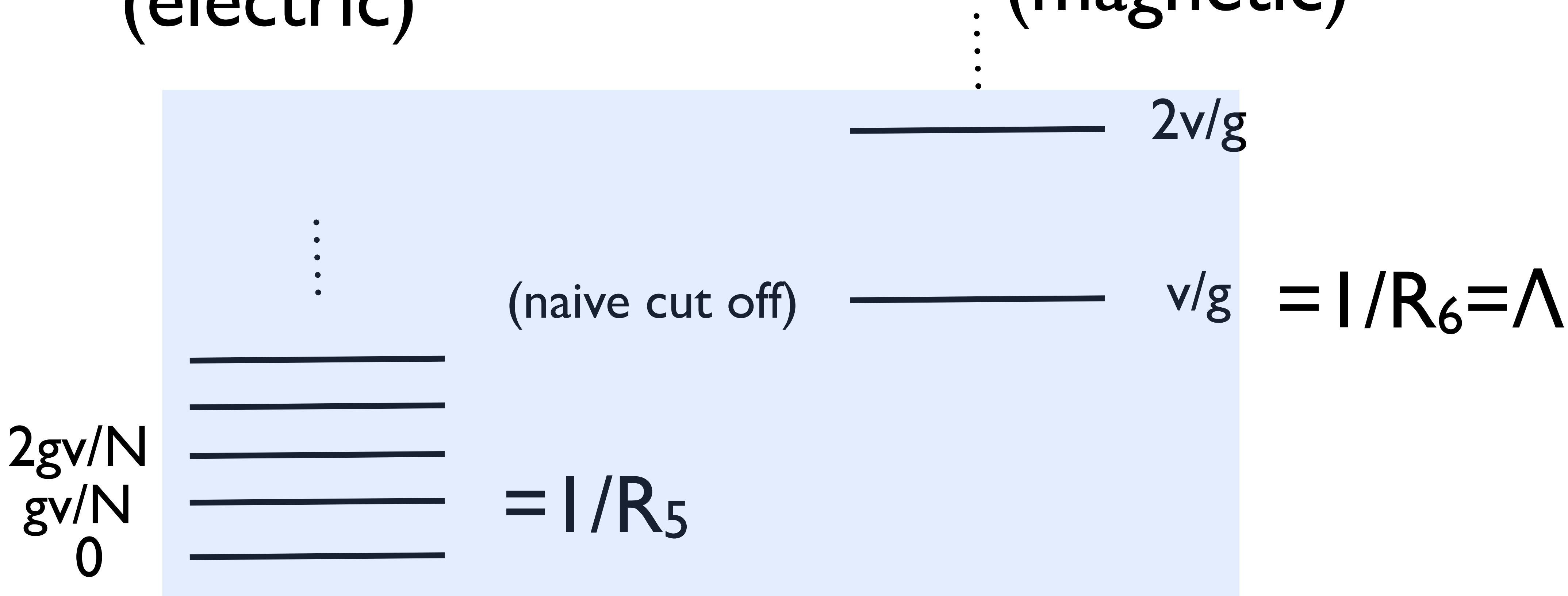
$\longrightarrow$ no problem with a large g.

$\longrightarrow$ We can go beyond $\Lambda$!!

[Arkani-Hamed, Cohen, Kaplan, Karch, Motl '01]

# 6th dimension

KK modes (electric) $\xleftrightarrow{\text{S-dual}}$ another KK tower (magnetic)

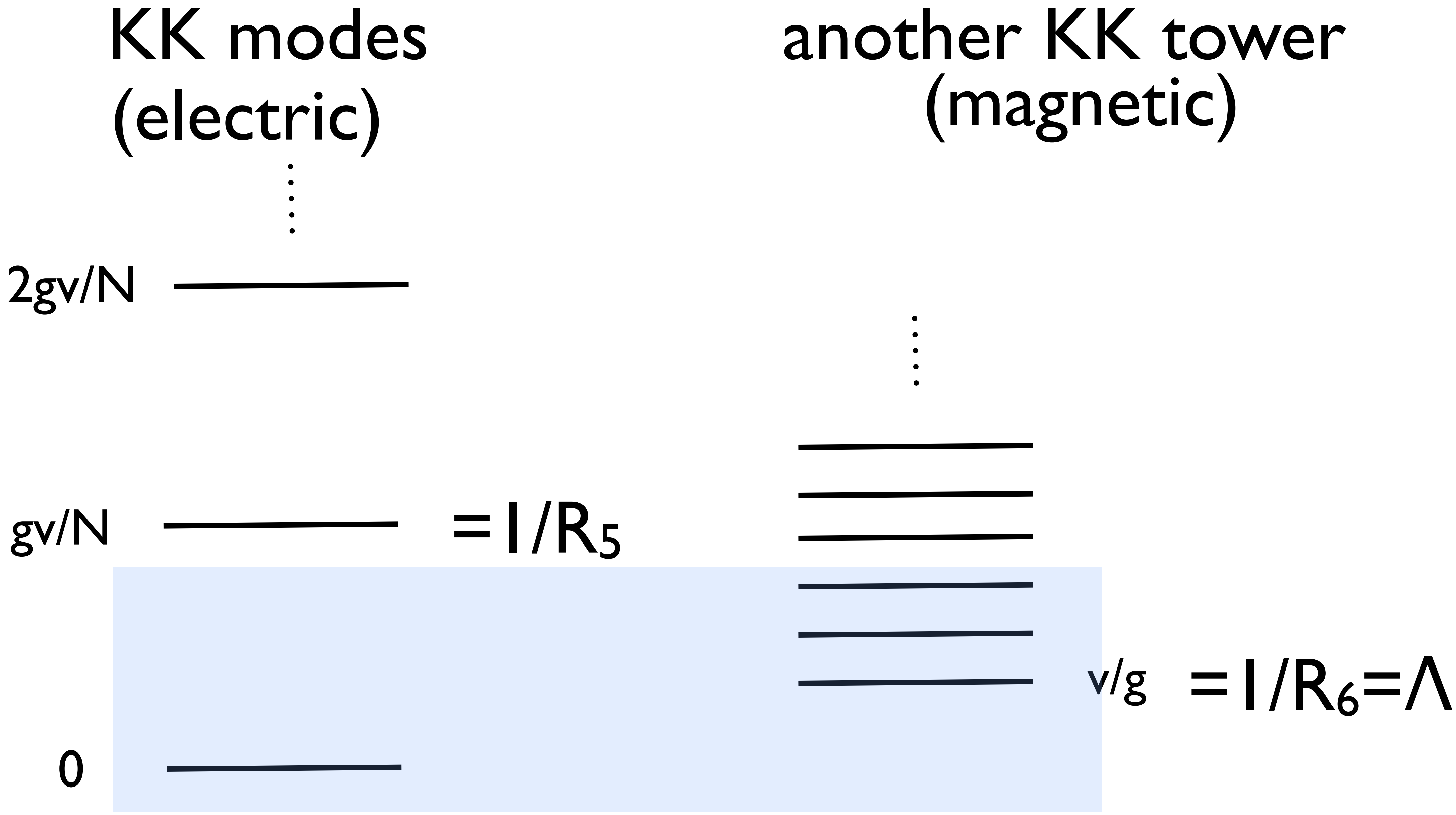



appearance of 6th dimension

Interesting.

# $1/R_5 \gg \Lambda$ means,

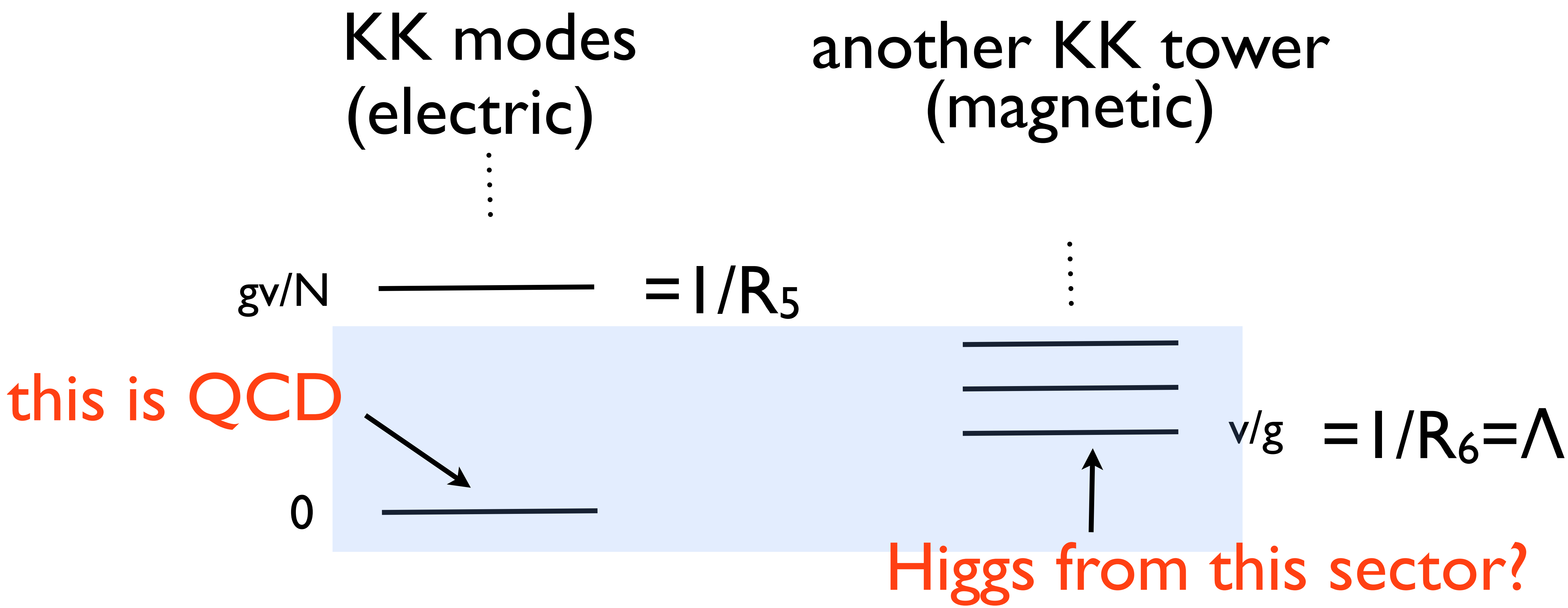
(small extra dim.)




magnetic picture gets better description.

# Emergent Higgs

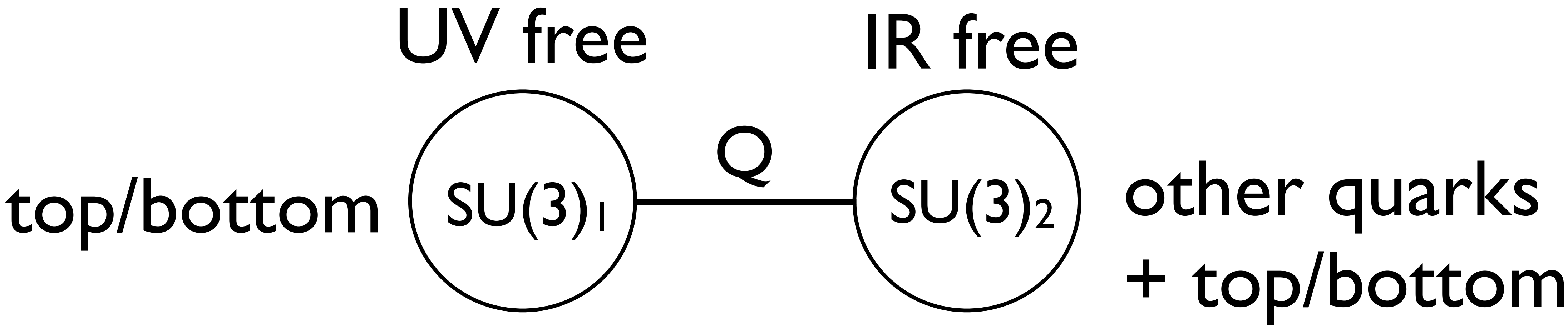
Higgs may be in the emergent degrees of freedom.




That would be an interesting unification.

# a toy model: 2-site model

[RK, Nakai '12]




Topcolor model [Hill '91]
[RK, Fukushima, Yamaguchi '10]
([Craig, Stolarski, Thaler '11][Csaki, Shirman, Terning '11][Cohen, Hook, Torroba '12][Evans, Ibe, Yanagida '12]...)

| | | $SU(3)_1$ | $SU(3)_2$ | $U(1)_B$ | $SU(2)_L \times U(1)_Y$ |
|---|---|---|---|---|---|
| N=2 structure | $Q$ | $3$ | $\bar{3}$ | $1$ | $1_0$ |
| | $\bar{Q}$ | $\bar{3}$ | $3$ | $-1$ | $1_0$ |
| | $\Phi$ | $1$ | $1+8$ | $0$ | $1_0$ |
| | $q_1$ | $3$ | $1$ | $1$ | $2_{1/6}$ |
| | $t_1^c$ | $\bar{3}$ | $1$ | $-1$ | $1_{-2/3}$ |
| | $b_1^c$ | $\bar{3}$ | $1$ | $-1$ | $1_{1/3}$ |
| | $q_2$ | $1$ | $3$ | $0$ | $2_{1/6}$ |
| | $t_2^c$ | $1$ | $\bar{3}$ | $0$ | $1_{-2/3}$ |
| KK modes | $b_2^c$ | $1$ | $\bar{3}$ | $0$ | $1_{1/3}$ |
| | $\bar{q}_2$ | $1$ | $\bar{3}$ | $0$ | $\bar{2}_{-1/6}$ |
| | $\bar{t}_2^c$ | $1$ | $3$ | $0$ | $1_{2/3}$ |
| | $\bar{b}_2^c$ | $1$ | $3$ | $0$ | $1_{-1/3}$ |

gauged
(Lagrange multiplier)
(<Q>=v is fixed)

no Higgs field

$$W = \sqrt{2}g \left( q_1 \bar{Q} \bar{q}_2 + t_1^c Q \bar{t}_2^c + b_1^c Q \bar{b}_2^c + \bar{Q}\Phi Q - v^2 \mathrm{Tr}\Phi + v_q \bar{q}_2 q_2 + v_t \bar{t}_2^c t_2^c + v_b \bar{b}_2^c b_2^c \right).$$

For $\Lambda_1 \ll 4\pi v$ (weak coupling)

$$SU(3)_1 \times SU(3)_2 \longrightarrow SU(3)_{1+2}$$

We get MSSM without Higgs as low energy theory.

Below, we study the case with

$$\Lambda_1 \gg 4\pi v \quad \text{(strongly coupled region)}$$

$\longrightarrow$ we will see that magnetic degrees of freedom appear.

# Seiberg duality [Seiberg '94]

$SU(3)_1$ factor gets strong

$\longrightarrow$ weakly coupled magnetic picture (CFT)

| | $SU(3)_1$ | $SU(3)_2$ | $U(1)_B$ | $SU(2)_L \times U(1)_Y$ |
|---|---|---|---|---|
| $Q$ | $3$ | $\overline{3}$ | $1$ | $1_0$ |
| $\bar{Q}$ | $\overline{3}$ | $3$ | $-1$ | $1_0$ |
| $\Phi$ | $1$ | $1+8$ | $0$ | $1_0$ |
| $q_1$ | $3$ | $1$ | $1$ | $2_{1/6}$ |
| $t_1^c$ | $\overline{3}$ | $1$ | $-1$ | $1_{-2/3}$ |
| $b_1^c$ | $\overline{3}$ | $1$ | $-1$ | $1_{1/3}$ |
| $q_2$ | $1$ | $3$ | $0$ | $2_{1/6}$ |
| $t_2^c$ | $1$ | $\overline{3}$ | $0$ | $1_{-2/3}$ |
| $b_2^c$ | $1$ | $\overline{3}$ | $0$ | $1_{1/3}$ |
| $\bar{q}_2$ | $1$ | $\overline{3}$ | $0$ | $\bar{2}_{-1/6}$ |
| $\bar{t}_2^c$ | $1$ | $3$ | $0$ | $1_{2/3}$ |
| $\bar{b}_2^c$ | $1$ | $3$ | $0$ | $1_{-1/3}$ |

$\longrightarrow$

Higgs appeared.

| | $SU(2)_1$ | $SU(3)_2$ | $U(1)_B$ | $SU(2)_L \times U(1)_Y$ |
|---|---|---|---|---|
| $f$ | $2$ | $1$ | $3/2$ | $2_0$ |
| $\bar{f}_u$ | $\overline{2}$ | $1$ | $-3/2$ | $1_{1/2}$ |
| $\bar{f}_d$ | $\overline{2}$ | $1$ | $-3/2$ | $1_{-1/2}$ |
| $H_u$ | $1$ | $1$ | $0$ | $2_{1/2}$ |
| $H_d$ | $1$ | $1$ | $0$ | $2_{-1/2}$ |
| $f'$ | $2$ | $3$ | $3/2$ | $1_{1/6}$ |
| $\bar{f}'$ | $\overline{2}$ | $\overline{3}$ | $-3/2$ | $1_{-1/6}$ |
| $q$ | $1$ | $3$ | $0$ | $2_{1/6}$ |
| $t^c$ | $1$ | $\overline{3}$ | $0$ | $1_{-2/3}$ |
| $b^c$ | $1$ | $\overline{3}$ | $0$ | $1_{1/3}$ |

below the dynamical scale $\Lambda_1$.

# weakly coupled

a-maximization gives [Intriligator, Wecht '03]

$$D(H_d) = 1.03, \quad D(H_u) = 1.13, \quad D(q) = 1.13, \quad D(t^c) = 1.17,$$

$$D(f) = 0.99, \quad D(\bar{f}_u) = 0.99, \quad D(\bar{f}_d) = 0.88, \quad D(f') = 0.84, \quad D(\bar{f}') = 0.88.$$

$$\longrightarrow \quad \frac{\tilde{g}}{4\pi} \sim 0.41, \quad \frac{\lambda_d}{4\pi} \sim 0.11, \quad \frac{\lambda_u}{4\pi} \sim 0.26, \quad \frac{\lambda_t}{4\pi} \sim 0.29, \quad \frac{\lambda_q}{4\pi} \sim 0.26,$$

(we assumed $\lambda_b \ll 4\pi$ by taking small $v_b$)

$$W = \lambda_d \bar{f}_u H_d f + \lambda_u \bar{f}_d H_u f + \lambda_t \bar{f}_u t^c f' + \lambda_b \bar{f}_d b^c f' + \lambda_q \bar{f}' q f + \frac{(4\pi v)^2}{\Lambda_1} \bar{f}' f',$$

$$= \Lambda'$$

$$\Lambda_1 \gg 4\pi v \longrightarrow \Lambda' \ll 4\pi v$$ (appearance of light degrees of freedom)

# below Λ’

Partially composite Higgs
[RK, Luty, Nakai ’12]

$$W = \lambda_d \bar{f}_u H_d f + \lambda_u \bar{f}_d H_u f - \frac{\lambda_q \lambda_t}{\Lambda'} f \bar{f}_u t^c q - \frac{\lambda_q \lambda_b}{\Lambda'} f \bar{f}_d b^c q.$$

SU(2)$_1$ factor confines

(note: at this stage, λ’s get renormalized by O(1) factors.)

$$\longrightarrow \quad W = \frac{\lambda_u \Lambda'}{4\pi} H_u H'_d + \frac{\lambda_d \Lambda'}{4\pi} H_d H'_u - \frac{\lambda_q \lambda_t}{4\pi} H'_u t^c q - \frac{\lambda_q \lambda_b}{4\pi} H'_d b^c q.$$

| | $SU(3)_2$ | $U(1)_B$ | $SU(2)_L \times U(1)_Y$ |
|---|---|---|---|
| $H_u$ | 1 | 0 | $2_{1/2}$ |
| $H_d$ | 1 | 0 | $2_{-1/2}$ |
| $H'_u$ | 1 | 0 | $2_{1/2}$ |
| $H'_d$ | 1 | 0 | $2_{-1/2}$ |
| $S$ | 1 | 3 | 1 |
| $\bar{S}$ | 1 | $-3$ | 1 |
| $q$ | 3 | 0 | $2_{1/6}$ |
| $t^c$ | $\bar{3}$ | 0 | $1_{-2/3}$ |
| $b^c$ | $\bar{3}$ | 0 | $1_{1/3}$ |

gauged

$$\left( H'_u H'_d - S\bar{S} = \frac{\Lambda'^2}{(4\pi)^2}. \right)$$

<H’> = 0
<S> ≠ 0
at SUSY level.

S is not dynamical
one can integrate them out.

# arriving at the MSSM-like model

$$W = \frac{\lambda_u \Lambda'}{4\pi} H_u H_d' + \frac{\lambda_d \Lambda'}{4\pi} H_d H_u' - \frac{\lambda_q \lambda_t}{4\pi} H_u' t^c q - \frac{\lambda_q \lambda_b}{4\pi} H_d' b^c q.$$

$$K \ni \frac{\Lambda'^\dagger}{\Lambda'} H_u' H_d' + \text{h.c.}$$

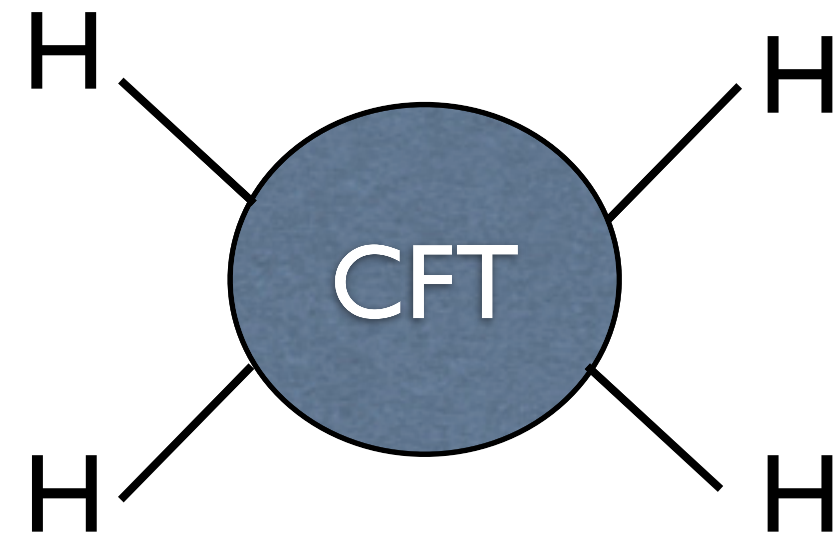
μ-like terms

obtained from kinetic terms for S and $\overline{\text{S}}$.

We consider SUSY breaking by turning on

$\Lambda'(1 + m_{\text{SUSY}}\theta^2)$ with $m_{\text{SUSY}} \sim \Lambda' \sim 1\ \text{TeV}$

# Higgs potential




$$V \ni \frac{m_{\mathrm{SUSY}}^2}{(4\pi)^2}(|\lambda_u H_u|^2 + \underline{|\lambda_d H_d|^2}) + \frac{1}{(4\pi)^2}(|\lambda_u H_u|^4 + |\lambda_d H_d|^4).$$

$$V \ni m_{\mathrm{SUSY}}^2(|H_u'|^2 + |H_d'|^2) + \cdots$$

$H_d$ is the main Higgs direction

$$V \ni m_{\mathrm{SUSY}}\left(\frac{\lambda_u \Lambda'}{4\pi} H_u H_d' + \frac{\lambda_d \Lambda'}{4\pi} H_d H_u' + \mathrm{h.c.}\right),$$

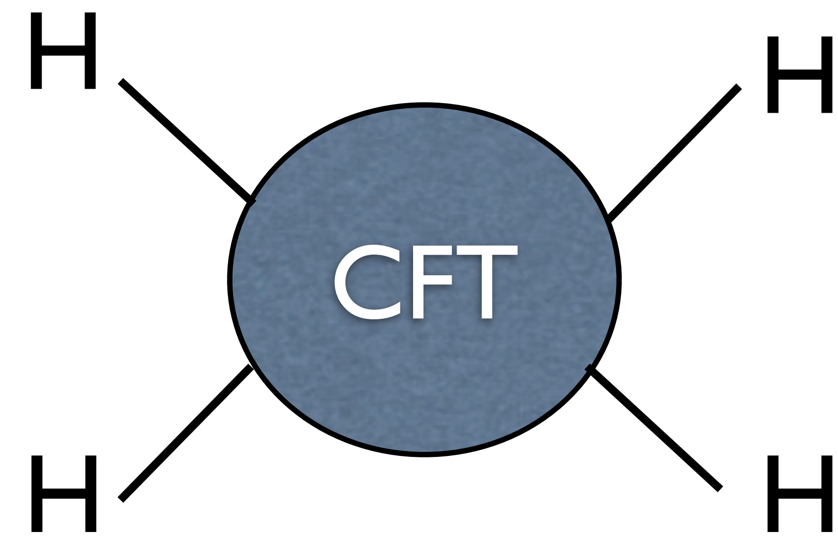
$$W \ni \frac{\Lambda'}{4\pi}(\lambda_u H_u H_d' + \lambda_d H_d H_u') + m_{\mathrm{SUSY}} H_u' H_d'.$$

H' are heavy

$$V \ni m_{\mathrm{SUSY}}^2 H_u' H_d' + \mathrm{h.c.}$$

Partially composite Higgs
[RK, Luty, Nakai '12]

$$m_h = 126\ \mathrm{GeV}$$




Higgs quartic term:

$$\frac{\lambda_d^4}{(4\pi)^2} + \frac{g_L^2 + g_Y^2}{2} \sim \frac{m_h^2}{\langle H \rangle^2} \sim 0.5, \qquad \frac{\lambda_d}{4\pi} \sim 0.2.$$

not bad.

tuning:

required size of the Higgs quadratic terms

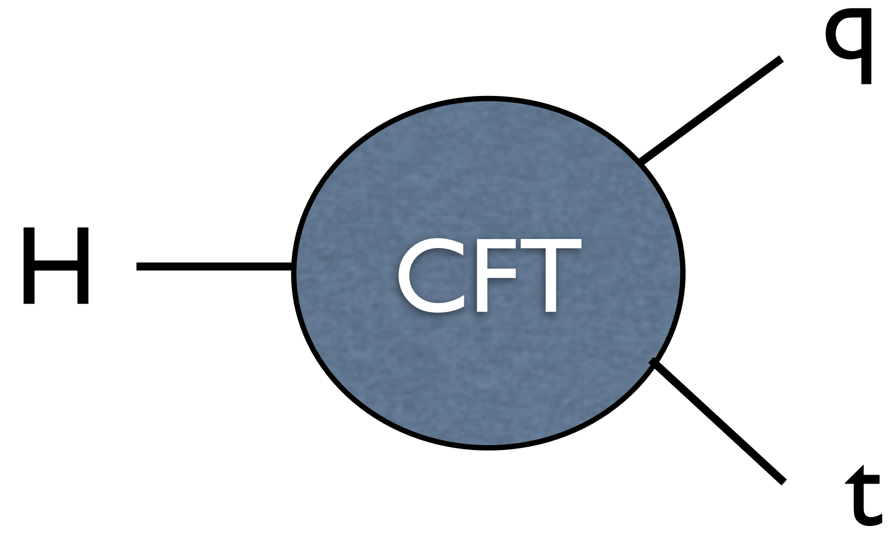
$$\delta = \frac{m_h^2/2}{(\lambda_d m_{\mathrm{SUSY}}/4\pi)^2,} = 20\% \cdot \left(\frac{m_{\mathrm{SUSY}}}{1\ \mathrm{TeV}}\right)^{-2} \left(\frac{\lambda_d/4\pi}{0.2}\right)^{-2}.$$

typical size

not bad.

fixed point values: $\frac{\tilde{g}}{4\pi} \sim 0.41, \quad \frac{\lambda_d}{4\pi} \sim 0.11, \quad \frac{\lambda_u}{4\pi} \sim 0.26, \quad \frac{\lambda_t}{4\pi} \sim 0.29, \quad \frac{\lambda_q}{4\pi} \sim 0.26,$

# top mass



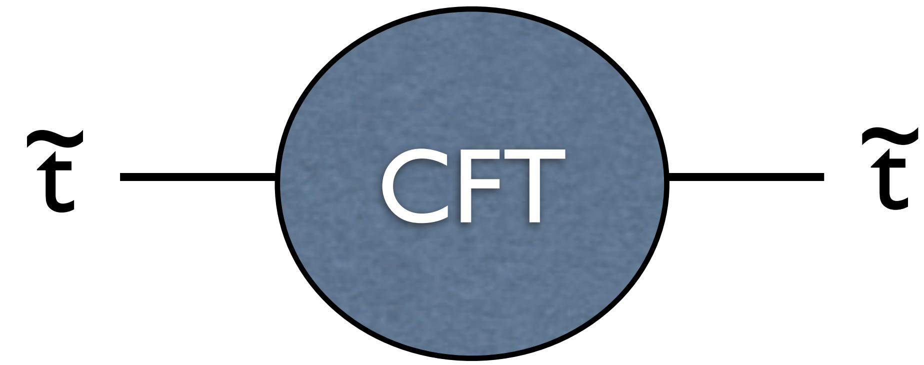

$$K \ni \frac{\lambda_q \lambda_t \lambda_d}{(4\pi)^2} \frac{1}{\Lambda'^\dagger} H_d^\dagger t^c q, \qquad W \ni -\frac{\lambda_q \lambda_t}{4\pi} H_u' t^c q \,.$$

$$\longrightarrow \quad m_t \sim \frac{\lambda_q \lambda_t \lambda_d}{(4\pi)^2} \langle H_d \rangle \sim 160 \text{ GeV} \cdot \left(\frac{\lambda_d/4\pi}{0.2}\right) \left(\frac{\lambda_q/4\pi}{0.6}\right) \left(\frac{\lambda_t/4\pi}{0.6}\right).$$

not bad.

note: top obtains a mass from $H_d$

fixed point values: $\frac{\tilde{g}}{4\pi} \sim 0.41, \quad \frac{\lambda_d}{4\pi} \sim 0.11, \quad \frac{\lambda_u}{4\pi} \sim 0.26, \quad \frac{\lambda_t}{4\pi} \sim 0.29, \quad \frac{\lambda_q}{4\pi} \sim 0.26,$

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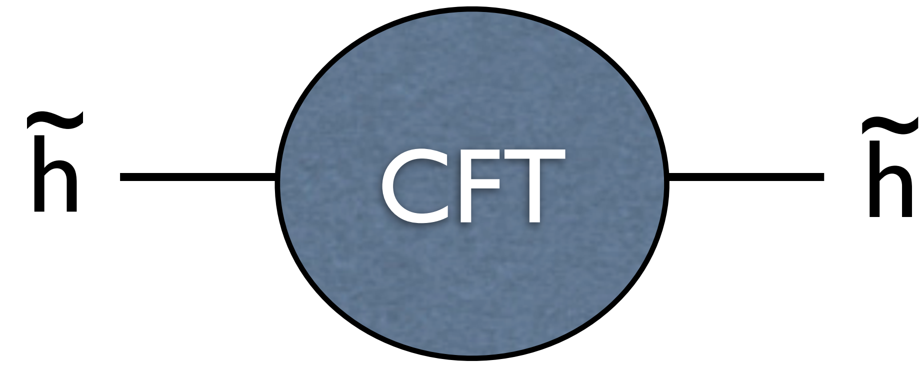
$$m_{\tilde{t}} \sim m_{\tilde{b}} \sim \frac{\lambda_q}{4\pi} m_{\text{SUSY}} \sim 600 \text{ GeV} \cdot \left(\frac{\lambda_q/4\pi}{0.6}\right)\left(\frac{m_{\text{SUSY}}}{1 \text{ TeV}}\right).$$

should be observed soon!

(should have been observed?)

fixed point values: $\frac{\tilde{g}}{4\pi} \sim 0.41, \quad \frac{\lambda_d}{4\pi} \sim 0.11, \quad \frac{\lambda_u}{4\pi} \sim 0.26, \quad \frac{\lambda_t}{4\pi} \sim 0.29, \quad \frac{\lambda_q}{4\pi} \sim 0.26,$




# Higgsino

$$m_{\tilde{h}} \sim \frac{\lambda_u \lambda_d}{(4\pi)^2} \frac{\Lambda'^2}{m_{\rm SUSY}} \sim 120 \text{ GeV} \cdot \left(\frac{\lambda_d/4\pi}{0.2}\right) \left(\frac{\lambda_u/4\pi}{0.6}\right) \left(\frac{\Lambda'}{1 \text{ TeV}}\right)^2 \left(\frac{m_{\rm SUSY}}{1 \text{ TeV}}\right)^{-1}.$$

pretty light.

fixed point values: $\frac{\tilde{g}}{4\pi} \sim 0.41, \quad \frac{\lambda_d}{4\pi} \sim 0.11, \quad \frac{\lambda_u}{4\pi} \sim 0.26, \quad \frac{\lambda_t}{4\pi} \sim 0.29, \quad \frac{\lambda_q}{4\pi} \sim 0.26,$

# dynamical sector

$$\Lambda' \sim 1 \text{ TeV}$$

We can access to UV dynamics of QCD.

We expect ρ-like resonances (W', Z')

very interesting.

# We saw that

EWSB may be a magnetic description
of higher dim. QCD.

↓

Can we also understand confinement/chiral symmetry
breaking in QCD as the Higgs mechanism
in the magnetic picture?

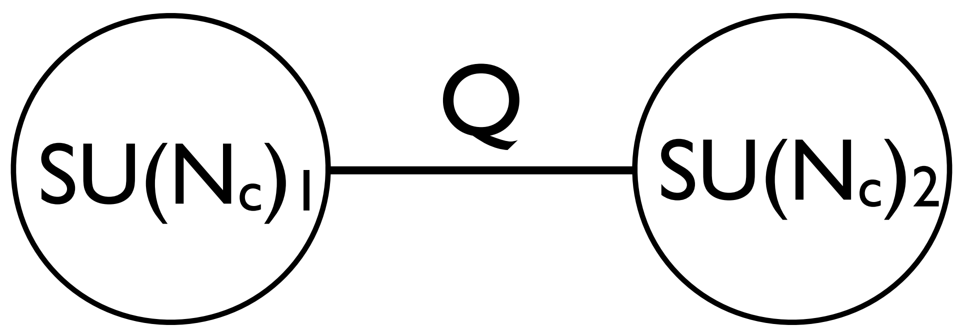
[Mandelstam '75, 't Hooft '75]

Maybe deconstruction and duality in SUSY theories
can provides us with a new insight.

# Regulating QCD to higher dimensional SQCD

$N_f$ quarks

[RK '11] [RK, Yokoi '14]

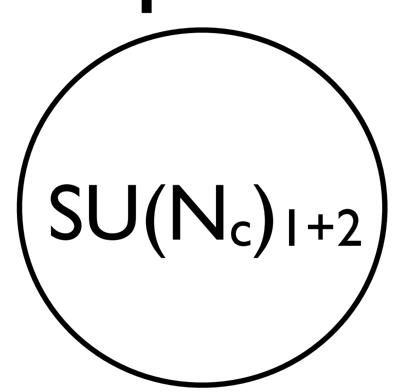



$(N_f < N_c)$

This provides an interesting deformation of QCD.

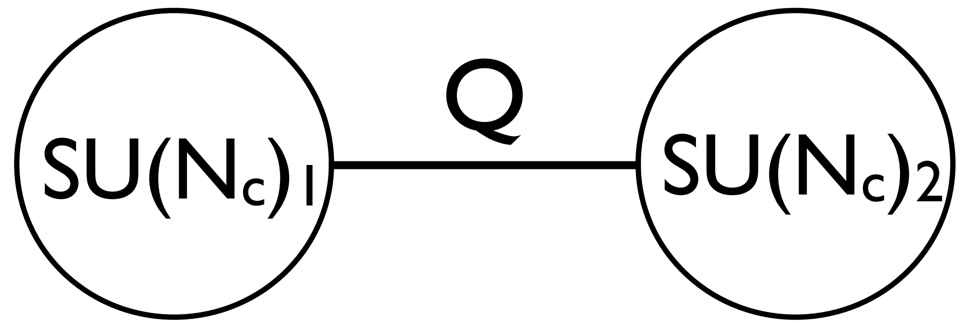
For $v \gg \Lambda_1, \Lambda_2$, this is just QCD.

$N_f$ quarks



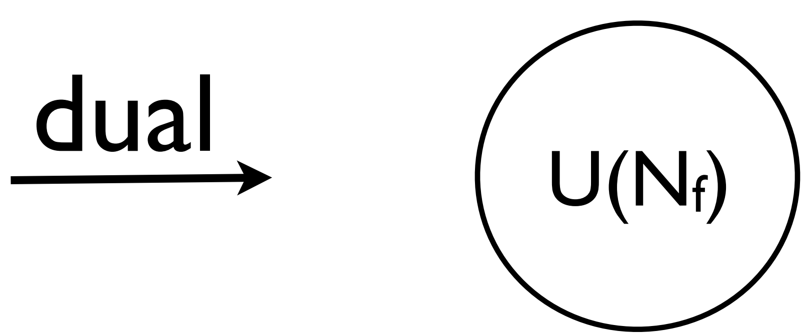
$$\Lambda_1 \gg \Lambda_2 \gg v$$

$N_f$ quarks




Starting with N=2 SUSY and
adding a small breaking of N=2 SUSY to N=1

$N_f$ dual quarks

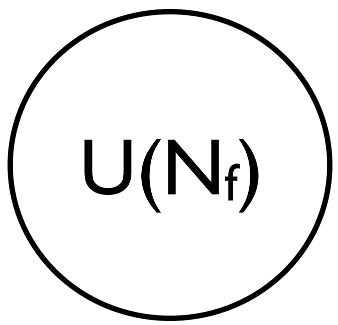



magnetic picture

# color-flavor locking

[See also Shifman and Yung '07, ...]

$N_f$ dual quarks




turning on v

$$\langle q \rangle = \langle \bar{q} \rangle = \begin{pmatrix} v/\sqrt{N_c} & & \\ & \ddots & \\ & & v/\sqrt{N_c} \end{pmatrix}$$

magnetic gauge bosons of $U(N_f)$ behave as vector mesons ρ and ω.

string formation from U(1) breaking $\longrightarrow$ confinement

[Mandelstam '75, 't Hooft '75]

low energy QCD as magnetic picture?

[RK '11]

# N=0?

## Seiberg duality + soft SUSY breaking terms

electric

| | $SU(N_c)$ | $SU(N_f)_L$ | $SU(N_f)_R$ | $U(1)_B$ | $SU(N_c)_V$ | $U(1)_{B'}$ | $U(1)_R$ |
|---|---|---|---|---|---|---|---|
| $Q$ | $N_c$ | $N_f$ | 1 | 1 | 1 | 0 | $(N_f - N_c)/N_f$ |
| $\overline{Q}$ | $\overline{N_c}$ | 1 | $\overline{N_f}$ | $-1$ | 1 | 0 | $(N_f - N_c)/N_f$ |
| $Q'$ | $N_c$ | 1 | 1 | 0 | $\overline{N_c}$ | 1 | 1 |
| $\overline{Q}'$ | $\overline{N_c}$ | 1 | 1 | 0 | $N_c$ | $-1$ | 1 |

Table 1: Quantum numbers in the electric picture.

magnetic

| | $SU(N_f)$ | $SU(N_f)_L$ | $SU(N_f)_R$ | $U(1)_B$ | $SU(N_c)_V$ | $U(1)_{B'}$ | $U(1)_R$ |
|---|---|---|---|---|---|---|---|
| $q$ | $N_f$ | $\overline{N_f}$ | 1 | 0 | 1 | $N_c/N_f$ | $N_c/N_f$ |
| $\overline{q}$ | $\overline{N_f}$ | 1 | $N_f$ | 0 | 1 | $-N_c/N_f$ | $N_c/N_f$ |
| $\Phi$ | 1 | $N_f$ | $\overline{N_f}$ | 0 | 1 | 0 | $2(N_f - N_c)/N_f$ |
| $q'$ | $N_f$ | 1 | 1 | 1 | $N_c$ | $-1 + N_c/N_f$ | 0 |
| $\overline{q}'$ | $\overline{N_f}$ | 1 | 1 | $-1$ | $\overline{N_c}$ | $1 - N_c/N_f$ | 0 |
| $Y$ | 1 | 1 | 1 | 0 | $1 + \text{Adj.}$ | 0 | 2 |
| $Z$ | 1 | 1 | $\overline{N_f}$ | $-1$ | $\overline{N_c}$ | 1 | $(2N_f - N_c)/N_f$ |
| $\overline{Z}$ | 1 | $N_f$ | 1 | 1 | $N_c$ | $-1$ | $(2N_f - N_c)/N_f$ |

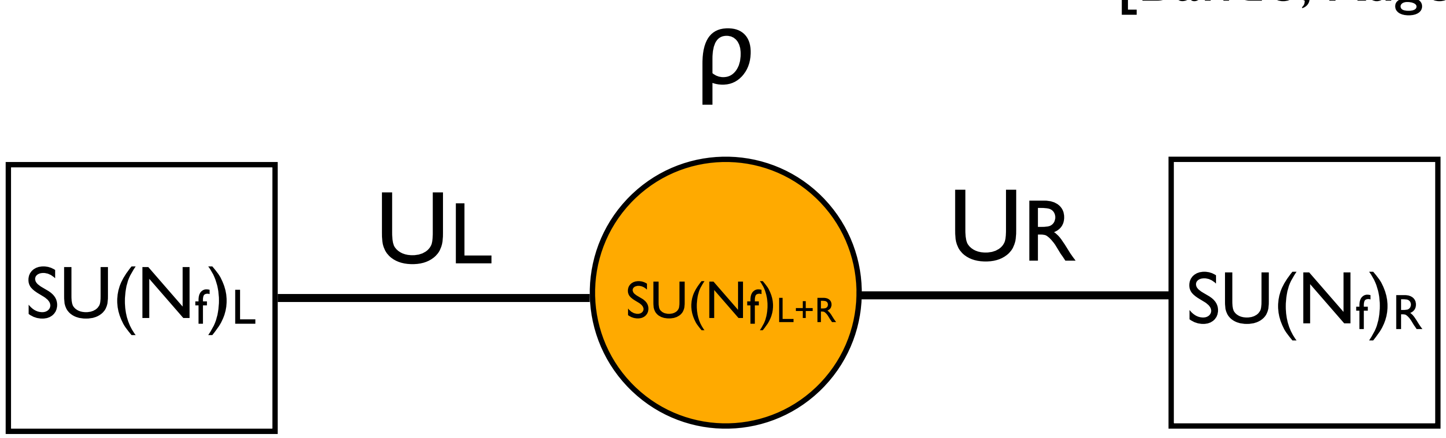
Tachyonic

One can also see the Color-Flavor Locking.

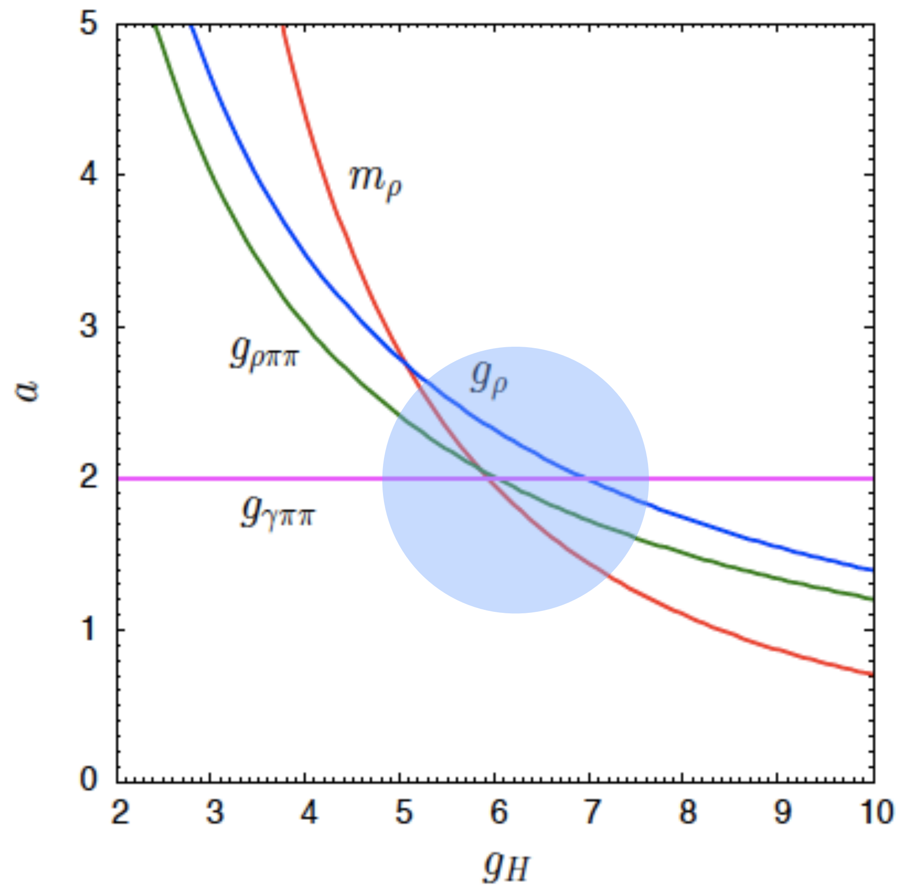
# May not be totally crazy.

## Hidden Local Symmetry

[Bando, Kugo, Uehara, Yamawaki, Yanagida '85]




$$
\begin{aligned}
\mathcal{L} \;=\; & -\frac{1}{4g_H^2}F^a_{\mu\nu}F^{a\mu\nu} \\
& +\frac{af_\pi^2}{2}\mathrm{tr}\left[|D_\mu U_L|^2+|D_\mu U_R|^2\right] \\
& +\frac{(1-a)f_\pi^2}{4}\mathrm{tr}\left[|\partial_\mu(U_LU_R)|^2\right].
\end{aligned}
$$




We see such a picture in the real world.

Quiver deformation provides us with
an understanding of HLS as
the magnetic gauge theory.

weak coupling $\longleftrightarrow$ strong coupling

| QCD | HLS as magnetic theory |
|---|---|

large extra dim. $\longleftrightarrow$ small extra dim.

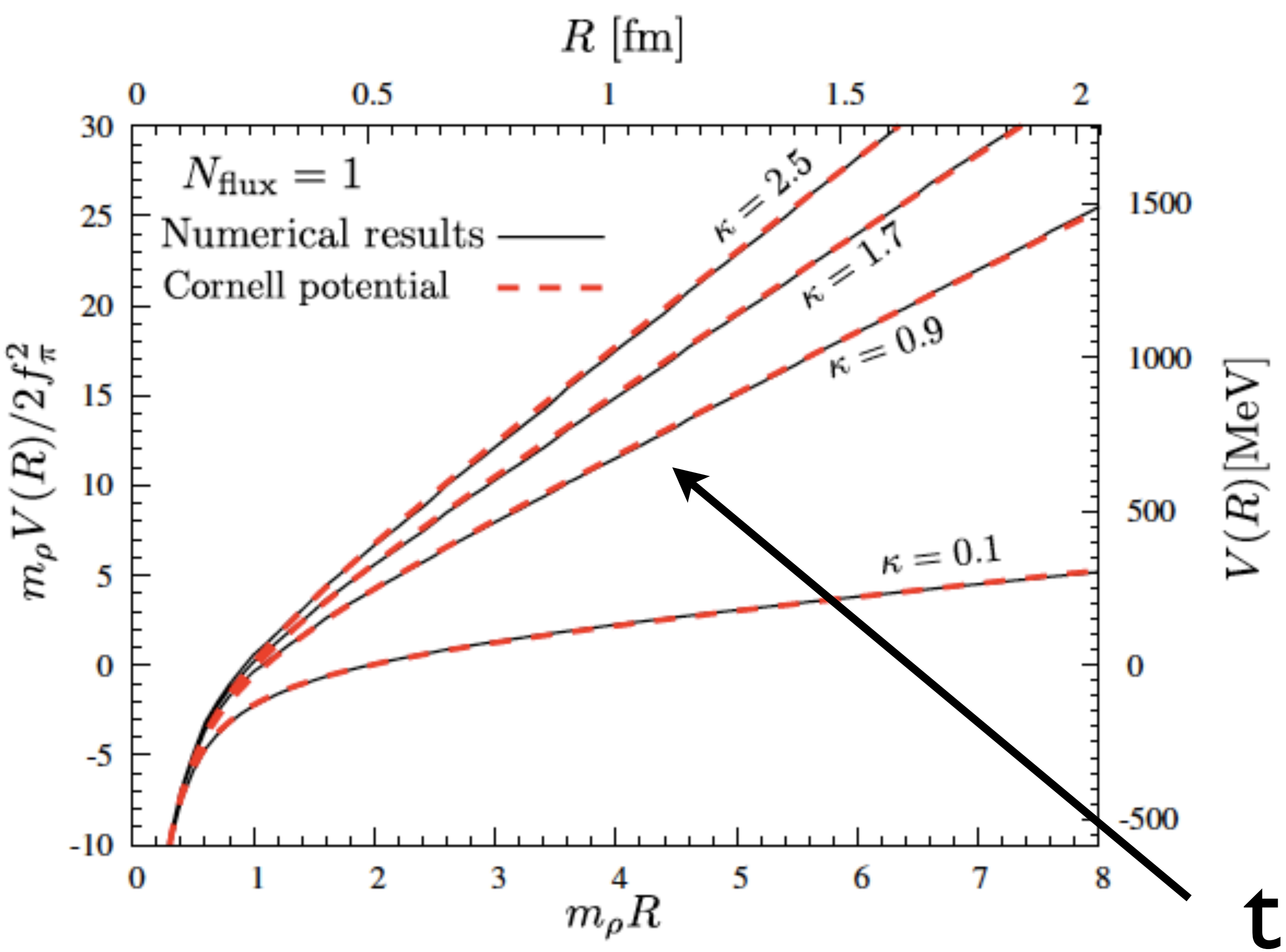
See also

[Seiberg '95, Harada, Yamawaki '99, Komargodski '10, RK '11, Abel, Barnard '12]

[RK, Nakamura, Yokoi '12]

# Moreover,

one can construct a string configuration made of ρ, ω, and $f_0$ and calculate an energy.




this line

$$g_\rho = (340\ \mathrm{MeV})^2,$$

$$m_\rho = 770\ \mathrm{MeV},$$

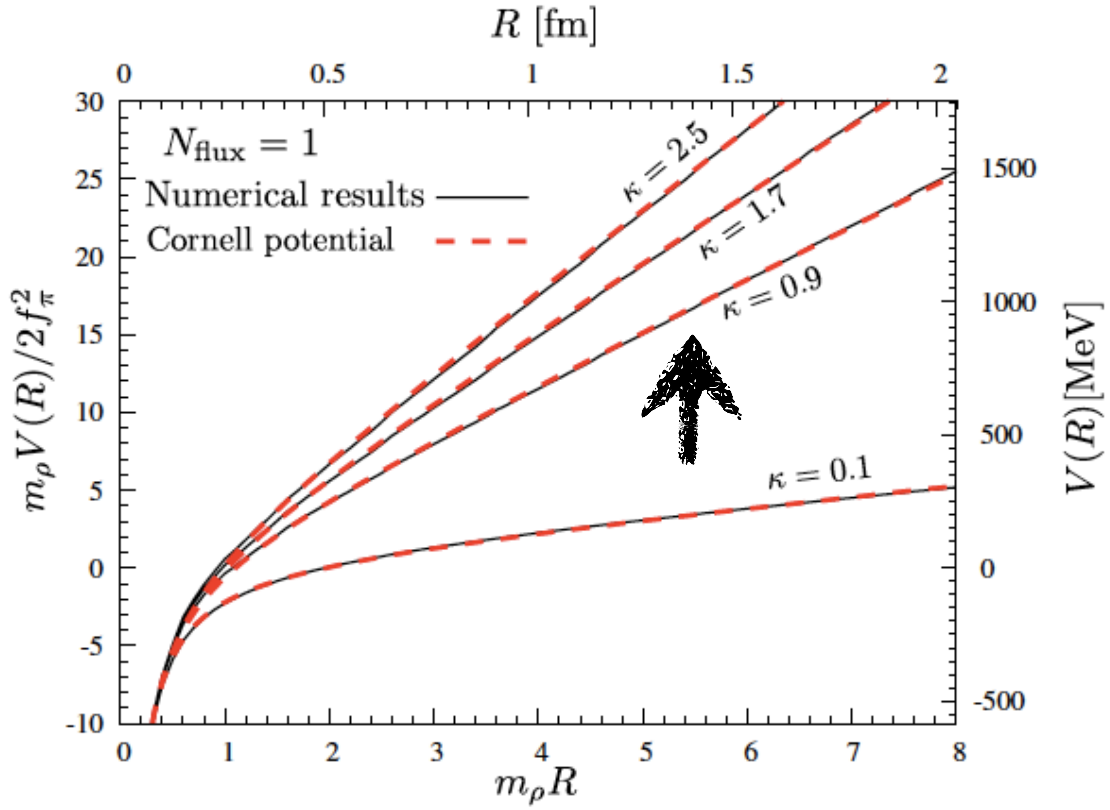
~ $m_\omega$

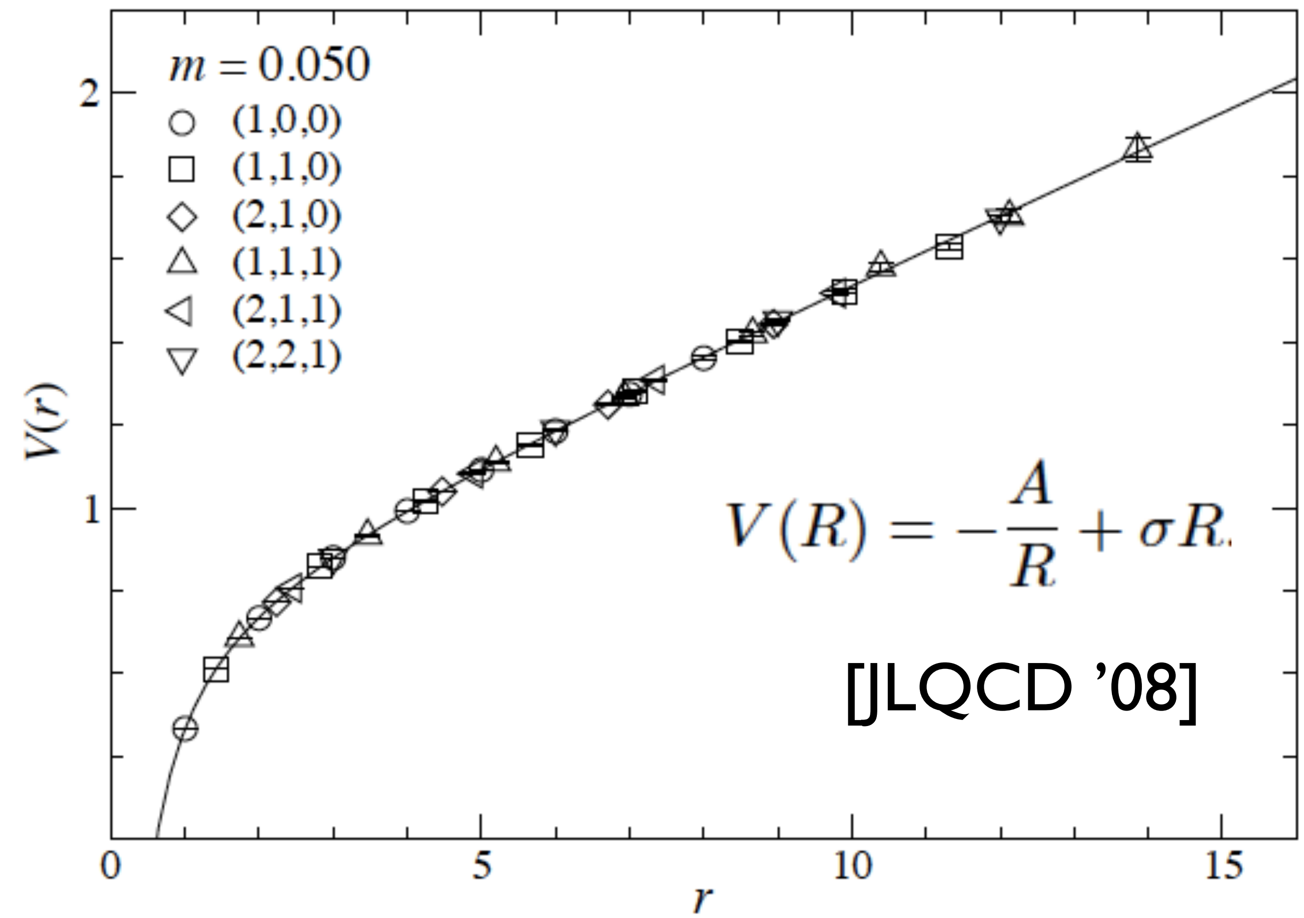
$$m_S = m_A = 980\ \mathrm{MeV},$$

(scalar meson masses)

$$V(R) = -\frac{A}{R} + \sigma R. \qquad A = 0.25 \quad \sqrt{\sigma} = 400\ \mathrm{MeV}$$

# Comparing to lattice QCD




$A = 0.25 \qquad \sqrt{\sigma} = 400\ \mathrm{MeV}$

$A \sim 0.25 - 0.5, \quad \sqrt{\sigma} \sim 430\ \mathrm{MeV}.$

pretty consistent.

confining string $\stackrel{?}{=}$ hadron vortex

# Summary

- We studied a quiver model for EWSB. The Higgs fields emerge as magnetic degrees of freedom. By adding SUSY breaking terms, EWSB can occur while 126GeV Higgs boson is naturally explained.

- Confinement and Chiral Symmetry Breaking in QCD may also have a picture of the Higgs mechanism via duality.